ASPHYXIA

ITS NATURE AND ITS REMEDY.

Unica spes est, unicum remedium.

— *sævam exhalat .... Mephitim.*

Virg, Æn. *Lib.* vii, *l.* 84.

ABSTRACT OF AN INVESTIGATION

INTO

ASPHYXIA;

ITS NATURE, CARBONIC ACID BLOOD-POISONING, AND ITS
REMEDY, PRONE AND POSTURAL RESPIRATION;

PRESENTED TO

THE ROYAL HUMANE SOCIETY

BY

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TO THE MEMORY OF THE LATE

DR. HAWES,

THE BENEVOLENT

FOUNDER OF THE ROYAL HUMANE SOCIETY.

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Additional Experiments.

* I placed a white mouse in about two ounces of pure oxygen gas: it breathed naturally, then panted, then sighed, and then gasped. It was removed in twenty-five minutes, and was slightly convulsed, and still gasped when in the open air; it tottered in its movements. The residual gas brightened the *spark* of a taper lighted and blown out; it therefore contained much oxygen, and the phenomena were exclusively those of carbonic acid. *Vide page* 19.

I placed a mouse in a large quantity of pure oxygen gas: it remained during three or four hours without manifesting any change, and was then removed apparently little affected.

‡ The subject, a girl, aged 5 years. On pronation of the body, air was expelled in considerable quantity through the water in the inverted glass siphon. On rotation, air entered to a corresponding amount. This was repeated 7 or 8 times.

The body was again pronated with the same results as regards expiration. It was then raised by hands placed under the hips and shoulders. Good inspiration took place, but not to the same extent as on rotation. This was repeated 3 or 4 times. *Vide page* 31.

The efficacy of rotation was again manifested in a subsequent experiment witnessed by Mr. Williams.

ASPHYXIA

ITS NATURE AND ITS REMEDY.

§ I.—*Introduction.*

In the following pages I propose to treat of Asphyxia, its rationale and its treatment, in so succinct and plain a manner as to be useful to those most interested in the *practical* results of such inquiries. I shall keep in view that it is to promote the benevolent objects of the Royal Humane Society that my efforts are made.

My first aim will be to give a clear view of the *nature* of the effects of suspended respiration; my second, to state the best means of restoring the patient affected by that suspension.

The nature of normal respiration is entirely different from that of the apparently respiratory movements in asphyxia. The former are, as will be more distinctly explained hereafter, *reflex;* that is, they are *excited* by the carbonic acid exhaled from the blood into the air-cells of the lungs, through nerves which proceed to the spinal *centre,* traverse it in some mysterious manner, and proceed from that centre to the muscles of respiration. The latter are *centric,* and are caused by the action of the carbonic acid retained in the blood, acting on the spinal centre itself and through certain nerves which proceed from it to the muscles moved, which are also different from the former ones.

This distinction, which is of the utmost importance, has been established by my own experiments.

During the circulation, the oxygen inhaled in respiration unites with the carbon in the blood, forming carbonic acid. This carbonic acid is exhaled in respiration in its turn, except in the cases in which the respiration is suspended, as in drowning and other forms of asphyxia.

In asphyxia, the carbonic acid retained in the blood first poisons the brain, producing anæsthesia, unconsciousness, and immobility; and then the spinal centre, producing the gaspings so characteristic of this condition, and constituting the last *external* sign of life.

After this there is still a slight lingering movement of the heart, on which the feeble hopes of the restoration of the patient repose; but speedily true asphyxia (from α and σφυζω, pulso), or the cessation of all pulsation and circulation occurs.

Such is the course of events when the suspension of respiration is complete. It is usually rapid and of short duration. Sometimes, however, the suspension of respiration is not absolute; the patient may rise to the surface and breathe; or there may be a state of *syncope*, or of *shock*, produced by the circumstances of the accident and inducing a *feeble circulation;* and then the duration of the asphyxia, with the hope of restoration, is more protracted, that hope being directly as the persistence of the respiration and inversely as the rapidity of the circulation.

The further hope of restoration by the means we employ is again directly as we *excite* or *imitate* respiration, the restoration of the circulation being promoted by shampooing, the warm bath, &c. only as subsidiary and *secondary* to respiration.

We must never forget that the circulation is a *self*-poisoning, the respiration a *de*-poisoning process. These are the two principles by which we must be guided in our treatment of asphyxia. On these topics I proceed to treat more at length in the subsequent sections. I beg my reader to pardon a few repetitions.

§ II.—*The Distinction between Respiration and the Respiratory Movements in Asphyxia.*

Every one is familiar with the effect of dashing cold water on the face, or of descending slowly into the cold bath. The cutaneous nerves of the face or general surface are impressed with the cold, and *excite*, through a reflex action performed through these nerves and the spinal centre, acts of inspiration.

Every one has experienced the effect on the nostrils of the carbonic acid evolved from the stomach after taking draughts of soda water.

In ordinary circumstances it is the carbonic acid *gas*, exhaled from the blood through the fine membranous tissues of the pulmonary air-cells, which, by exciting the fine fibrillæ of the pneumogastric nerve spread over those air-cells, proves the constant *excitant*, through those nerves and the spinal centre, of the normal acts of respiration.

To be more explicit, I may add that, in respiration, oxygen gas is inspired; it is absorbed into the arterial blood, and circulated with it; in its course it unites with carbon, and forms carbonic acid; this circulates in the venous blood in its turn, is exhaled from it, proves the excitant of a fresh inspiration in the pulmonary air-cells, and is finally expired into the atmospheric air.

These acts I have designated reflex or *dia*staltic, because they are performed along certain *in*-going nerves, *through* the spinal centre, and along certain *out*-going nerves eventually distributed to the muscles of respiration. This *dia*staltic action is the essential character of the *physiological* acts of respiration.

All is changed in the case in which the normal acts of respiration are obstructed, or in what is designated, however erroneously, by the term asphyxia.

When the respiration is entirely suspended, there is no exhalation of carbonic acid, the excitant of respiration; there can therefore be no *dia*staltic respiration; but the carbonic acid which ought to be exhaled in the lungs is retained in the blood, poisons it, circulates with it through the system and its various organs, and excites various abnormal conditions and actions. The mode of action is now not *dia*staltic, but centric in the spinal centre and *ec*staltic. The respiratory movements are no longer normal and rhythmic acts of inspiration and expiration, but abnormal and irregular *ex*piratory movements, with a peculiar opening of the mouth, flexion of the body, and frequently with the ejection of foam. Such is the character of the respiratory movements in asphyxia. They are *pathological*, not physiological; and they are, I repeat, centric or *ec*staltic *from* the spinal centre, not *dia*staltic, *through* it.

The blood is poisoned by the carbonic acid so retained; the organs are poisoned in their turn by this blood-poison. Our most strenuous efforts must be exerted to eliminate and remove this poison from the blood and from the system. All other efforts are subsidiary, although auxiliary; and, if they at all take the place of this, injurious.

The *only* mode of thus eliminating the carbonic acid blood-poison is, to *excite*, or *imitate*, respiration—the one idea which it is the object of these pages to enforce.

Adopting fully the beautiful device of the Royal Humane Society, I would carry out its meaning still further, and say that so to *blow* the latent spark into flame, is our hope, our only hope:—*unica spes est, unicum remedium.*

To revert to the specific topic of this section, I would again say—and it is entirely the result of my own labours—that whilst the normal respiratory movements are *reflex* in their mode of excitement, the movements in asphyxia are *centric*. Of the former character too is the *panting*, which may be designated *hyper*pnœa, observed in some experiments to be detailed hereafter; and of the latter, the peculiar phenomenon of *gasping*, which may be termed, from its equivocal character, *pseudo*pnœa.

§ III.—*Relation of Respiration to the Circulation.*

There is the strictest relation between the rapidity of the circulation and that of the respiration. The number of the pulsations of the heart preserves in all physiological conditions the same *ratio* to the number of respiratory movements. If the circulation be augmented, the respiration becomes more frequent; if the circulation be retarded, the respiration is proportionately slower.

This ratio between the number and force of the contractions of the heart and the number of the acts of respiration is physiological, the result of cause and effect, and essential to life and health.

As the blood circulates, it receives the vivifying effect of oxygen, and forms carbonic acid. This carbonic acid is exhaled through the fine membranous tissue of the air-cells, and coming then in contact with the minute *origins* of the pneumogastric nerve, the internal excitor respiratory nerve, excites the successive acts of respiration.

The formation and the evolution of this carbonic acid is greater in proportion to the quickness of the circulation; the rapidity of the respiration is proportionate to the quantity of this carbonic acid so formed and so evolved.

The circulation is rendered more rapid by muscular effort, and diminished by repose. It is more rapid during walking, less so during quiescence and sleep; it is reduced to its minimum, physiologically, during the continued sleep of hibernation. The rapidity of the respiration is *proportionate* to that of the circulation in all these conditions.

The circulation *without* respiration would be a *self*- or *blood*-poisoning process; respiration is *de*-poisoning. By respiration the carbonic acid poison formed during the circulation is eliminated from the blood and evolved from the system. Its *final* purpose requires that it should be, what it is, *proportionate* to the circulation. The carbonic acid, when evolved from the blood, no longer a poison, excites the respiration, which conveys it from the system—a wonderful adaptation of the means to the end!

In the state of hibernation, or extreme quiescence, the velocity of the circulation is reduced to its minimum; that of the respiration is *proportionately* reduced.

In the state of extreme activity, the velocity of the circulation is augmented to its maximum: whilst that of the respiration is *proportionately* augmented.

In the intermediate conditions of animal life, intermediate phenomena of circulation and of respiration are observed.

These interesting phenomena are, I repeat, readily explained. The *excitant* of ordinary respiration is the carbonic acid gas, evolved by the blood circulating in the fine membranes of the air-cells, and diffused into the contiguous atmospheric air. This evolution of carbonic acid from the circulating blood is proportionate to the rapidity of the circulation; and since this carbonic acid is the excitant of the respiration, the rapidity of the respiration becomes proportionate to that of the circulation in its turn.

It is demonstrated by chemical analysis that the quantity of carbonic acid evolved is really augmented with the augmented rapidity of the circulation. When the rapidity of the circulation and the quantity of evolved carbonic acid are greatly augmented, the respiration becomes *panting*—a phenomenon observed when, without augmented circulation and evolution of carbonic acid, this latter gas is added in a certain proportion to the atmospheric air respired.

But that carbonic acid which, being evolved, thus performs a most important and vital function, becomes, if retained in the blood, as in suspended respiration, a deadly poison, as I shall proceed to show in the following sections; and as the quantity of the carbonic acid is augmented by every acceleration of the circulation, the rapidity of that process of poisoning is proportionately great.

§ IV.—*The Rationale of the Effects of Suspended Respiration.*

The phenomena of life result from the play of arterial blood on the nervous and muscular tissues.

The blood is supplied by the ingestion of food, and purified by the egestion of the fæces and urine. It is arterialized by the inhalation of oxygen and the exhalation of carbonic acid in respiration.

Respiration consists in these two processes; both of which are suspended when the respiratory movements are suspended, as in drowning or strangulation.

These two processes are of very different immediate value to life: the inhalation of oxygen may be long nearly suspended without proving fatal; the suspension of the exhalation of carbonic acid, even if incomplete, destroys life in a comparatively very short time. These facts are demonstrated by the following experiments:

Experiment 1. I placed an animal in a limited portion of nitrogen gas, which, from our imperfect mode of procedure, must have become mingled with a small portion of atmospheric air: it continued to breathe with freedom, only beginning to *pant* as the exhaled carbonic acid began to accumulate. *Vide* p. 44*.

Exp. 2. We placed an animal in carbonic acid: it began to *gasp* almost immediately, and soon expired.

In the first experiment the inhalation of oxygen was nearly excluded; in the second, the exhalation of carbonic acid was intercepted.

During the physiological condition of the functions, oxygen is continually inhaled, and carbonic acid exhaled. The former unites with the carbon in the blood and *forms* the latter. The carbonic acid, if retained, becomes a deadly poison. The blood, during its circulation, if respiration be suspended, proves *self-poisoning*, by the carbonic acid so formed and retained. This process of self-poisoning is rapid in proportion to the rapidity of the circulation; a fact which explains many of the phenomena of asphyxia and of the effects of our remedies.

The process of self-poisoning of the blood from the suspension of respiration is readily traceable in experiment:

Exp. 3. We submerged an animal in water, and carefully watched the phenomena: there were during the *first* period after submersion *voluntary* efforts to escape; then, a *second* period of stillness, or *anæsthesia,* without attempts either to move voluntarily or efforts to respire, the retained carbonic acid poisoning the *brain*, and not escaping into the air-cells; then followed a *third* period, of *gasping*, which I propose to designate *pseudopnœa*, conjoining opening of the mouth and expiratory movements, with the rejection of foam, and resulting from the impression made by the carbonic-acid-poisoned blood on the spinal centre; at length the gaspings cease, the animal seems to be dead, but a lingering circulation, the value of which is not yet determined by experiment, remains, but quickly subsides into true *asphyxia.*

Exp. 4. Instead of submerging the animal under water, we placed it in a limited portion of atmospheric air (of about three times its own bulk), and observed the following phenomena: the breathing was at the first perfectly natural, unless it was excited by emotion; during a *second* period it became *panting* (*hyperpnœa*), the exhaled carbonic acid, when re-respired, acting as an excitant of the pnuemogastric nerves of the pulmonary air-cells; this second period passes very gradually into the *third*, or that of *gasping* or *pseudopnœa*, as the carbonic acid poison formed in the blood excites the spinal centre, a period and a condition further marked by *open mouth, starts,* a *tottering* gait, and *paralytic* weakness of the posterior extremities, all denoting affection of the spinal centre.

The third period very gradually passes into the fourth, or true asphyxia and death.

These phenomena proceed with a rapidity which is inversely proportionate to the age of the animal, to its temperature, to its degree of activity, and to its elevation in the zoological scale.

The general principle is further illustrated by the phenomena of submersion in animals in a state of hibernation:

Exp. 5. I submerged a bat, which was lethargic in an atmosphere of 36° Fahr., in water of 40°. It moved about a little and expelled bubbles of air from its lungs. It was kept submerged during sixteen minutes, and was then removed. It appeared uninjured by the experiment.

Exp. 6. I placed a hedgehog which had become so lethargic in an atmosphere of 40° Fahr. as not to awake to take food for several days, under the surface of water at 42° Fahr. It moved about and expelled air from the lungs. It was retained under the water during twenty-two minutes. It was then removed. It appeared uninjured.

These animals die as speedily as other warm-blooded animals, if submerged in a state of activity.

Cases are recorded of the human subject being restored after many minutes of submersion. It may well be doubted whether the facts so recorded were correctly observed. But if they were, it must be supposed that a state of *syncope*, or of *shock*, must have obtained at the moment of immersion, and the circulation have been reduced. Here it may especially be said—*cita mors venit - aut victoria læta.*

The great principle in regard to the duration of suspended respiration without a fatal issue, is—the degree of *slowness* of the *blood-poisoning* process of the circulation. Every thing which, within physiological limits, conduces to this effect prolongs life. Every thing which, without respiration, promotes the circulation, such as the warm-bath, frictions, &c. leads to speedier blood-poisoning and death.

It must be remembered that the blood is poisoned by carbonic acid, formed by and during the circulation, and that there is one remedy, which consists in the elimination of that poison, and that this is done by respiration alone.

§ V.—*Asphyxia chiefly the result of the Retention of Carbonic Acid.*

That asphyxia is not the result of the exclusion of oxygen, but of the retention of carbonic acid, has been already stated in general terms, together with *the one sole* efficacious mode of treatment deduced from it. I now proceed to detail experiments, at once full of the deepest physiological interest, and confirmatory of this view.

Exp. 7.—A tame mouse was placed in *two* ounces of nitrogen gas, not quite pure, as before: it soon began to *pant*, from re-respiring the exhaled carbonic acid, and shortly afterwards to *gasp*, from the influence of the action of the retained carbonic acid on the medulla oblongata; and in *five* minutes it was dead.

Exp. 8.—I now placed another tame mouse in *ten* ounces of the same gas: it remained in it during *fifty* minutes, neither panting nor gasping, its breathing becoming slower and feebler. It was removed, and seemed not to have suffered materially. The residual gas instantly and entirely extinguished a taper.

Exp. 9.—In another experiment, I placed a wild mouse in *four* ounces of similar gas. It began to pant in *three or four* minutes, and to open its mouth a little in *three or four* minutes *more*. It was then transferred into *eight* ounces of fresh nearly pure nitrogen. It remained in this gas *thirty* minutes, its respiration simply and gradually subsiding in depth and frequency to only forty-eight respirations in a minute. We then removed it, in a most feeble condition; it seemed to recover, however, and the next day was lively; but it died (of secondary asphyxia?) on the third. *See* p. 6*.

These experiments are amongst the most remarkable in physiology, and suggest many curious reflections: nearly all the carbonic acid existing in the blood is exhaled; and nearly all oxygen being excluded, little or no further carbonic acid can be formed. Respiration is reduced to its minimum; yet the animal lives, the blood *not* remaining or becoming poisoned by its carbonic acid.

I reserve the further observations on these and another series of experiments for a memoir which I am preparing for the Institute of France. My present object is to present brief *practical* views; my further object is to treat the subject of respiration, and its partial or complete and varied suspension, at greater length and in all its scientific relations.

An animal submerged in water dies very speedily, poisoned by the carbonic acid contained in the blood; and the more speedily, the quicker the circulation and the formation of that carbonic acid poison. *Gasping* is the premonitory sign of death.

An animal placed in a very limited portion of nearly pure nitrogen gas dies in the same manner, but more slowly, a part of the carbonic acid poison being evolved into that gas, and *panting* precedes the *gasping*.

In a large portion of nitrogen gas, or in a second portion of this gas, the first having received the portion of carbonic acid already formed in the blood, or nearly so, and no further carbonic acid being formed for want of oxygen, the animal, ceasing to experience the organic changes of respiration, and losing its temperature, simply sinks and dies, without the premonitory *panting* or *gasping*.

As natural respiration is the result of excitation of the pneumogastric nerves of the air-cells by the *evolved* carbonic acid; *panting* is the effect of *over*-excitation of these nerves by the carbonic acid *evolved* and by a portion of this gas *inspired;* whilst *gasping* is the consequence of the carbonic acid *retained* in the blood and brought by the circulation into contact with the medulla oblongata and spinalis. None of these events occur in a *large* or *second* portion of nearly pure nitrogen. The carbonic acid formed and evolved becomes less and less, with the gradual subsidence, therefore, of the acts of respiration, for want of the evolved carbonic acid excitant.

The phenomenon may be compared to the slow extinction of a taper in a limited portion of atmospheric air.

§ VI.—*On the Influence of Temperature, and on the Warm-Bath.*

We owe our knowledge of the influence of temperature in asphyxia to the splendid investigations of Edwards, and to the more recent experiments of M. Brown-Séquard.

Within certain limits, which may in general terms be fixed at 60° and 100°, Fahr. the duration of life in the case of suspended respiration is *inversely* as the temperature.

Above and below those temperatures respectively, heat and cold have each a directly injurious effect.

In illustration of these facts, I here adduce two invaluable *Tables*, giving the results of the experiments of Edwards and of M. Brown-Séquard :

Edwards's Table.[*]

Influence of temperature.—Kittens two days old asphyxiated by immersion in water :

	Mean duration of life.
At 32° Fahr.	4′ 33″
50_0	10′ 23″
68_0	38′ 45″
$78\frac{1}{2}{}_0$	34′ 30″
86°	29′
106°	10′ 27″

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[*] Des Agens Physiques; p. 630—.

*M. Brown-Séquard's Table.**

Influence of *previous* temperature.—Rabits two days old immersed in water of 77° Fahr. being first cooled—

	Mean duration of life.
To 96° Fahr.	12′
85°	18½′
74°	23′
65°	28′

It is obvious that the warm-bath, taken alone, must be utterly excluded in the treatment of asphyxia—that it can only be considered as admissible when respiration is either not extinct or admits of being excited, or is effectually imitated artificially.

There *is*, however, a use, not indeed for the warm bath, but for the *hot* bath, not hitherto suggested for adoption in practice: it is when it is of such elevated temperature, and when the patient is in such a condition, as to admit of its being an *excitant of respiration.*

Its use in this point of view is chiefly useful in the asphyxia of new-still-born infants; and I shall have to treat of it in this relation hereafter. But it cannot be doubted that, if it could be made available at the moment the patient is rescued from the water, a sudden momentary plunge into a bath of from 100° to 104° Fahr, would prove the most powerful *excitant* of inspiration.

But, even in this case, the application of the hot-bath must be momentary, and *alternated* with that of the cold-bath of the temperature of 50° or 60° Fahr. as an *excitant* of respiration in its turn.

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* (Researches, New York, 1853, p. 47.)

This suggestion I made some years ago to my much-lamented friend, Mr. Henry Smith, who, in one case, the only one on record, used it in the case of a still-born infant, with complete success.

We must cease therefore from the empirical use of the warm-bath. When this agent is used, it must either be administered as an excitant, not of the circulation, but of respiration; or as an excitant of the circulation, respiration being already restored, excited, or adequately imitated.

In confirmation of these results, I may here adduce four experiments, performed at the Royal Humane Society's receiving house in Hyde Park, and witnessed and recorded by Mr. Williams, its superintendent:

Exp. 10.—A kitten, three days old, 98° Fahr. in temperature, was submerged in water of the same temperature. Its last gasp was at the termination of 14½ minutes.

Exp. 11.—A kitten of the same age, after exposure alone to the cool atmosphere, was immersed in water of 50° Fahr. It survived 23 minutes!

Exp. 12.—We submerged a puppy, 66 hours old, under water at 100° Fahr. It endeavoured to escape, became still; then continued to gasp, frequently and quickly, during 19′ 35″: we counted 16 gasps.

Exp. 13.—We submerged a puppy of the same litter in water of 50° Fahr. It endeavoured to escape; became still, but in a less marked manner than the former one; gasped more slowly and at longer intervals during 39′ 35″! In this case we counted 24 gasps.

Judging from the *Table* of Edwards, the animal would have lived longer still in a temperature of 60° Fahr.; this temperature acting in prolonging life in asphyxia, whilst that of 50° destroys life as the direct effect of cold.

§ VII.—*The former Modes of Treatment of Asphyxia.*

The modes of the treatment of asphyxia hitherto proposed cannot be stated more distinctly than by the subjoined quotation of the *Rules* proposed by the Royal Humane Society.

" *To Restore the apparently Drowned.*

" 1. Convey the body carefully, with the head and shoulders supported in a raised position, to the nearest house.

" 2. Strip the body and rub it dry; then wrap it in hot blankets and place it in a warm bed, in a warm chamber free from smoke.

" 3. Wipe and cleanse the mouth and nostrils.

" 4. In order to restore the natural warmth of the body—move a heated covered warming-pan over the back and spine.

" Put bladders or bottles of hot water, or heated bricks, to the pit of the stomach, the arm-pits, between the thighs, and to the soles of the feet.

" Foment the body with hot flannels.

" Rub the body briskly with the hand; do not, however, suspend the use of the other means at the same time; but, if possible, immerse the body in a warm-bath at blood heat, or 100° of the thermometer, as this is preferable to the other means for restoring warmth.

"5. Volatile salts or hartshorn to be passed occasionally to and fro under the nostrils.

"6. No more persons to be admitted into the room than is absolutely necessary."

In addition to these rules, others are also recommended, and especially Leroy's mode of inducing artificial respiration by means of a bandage, so applied to the thorax as to admit of being tightened and relaxed.

But it will be sufficiently obvious to those who have read the preceding pages with attention, that our main objects in treating asphyxia are *two*: 1, to eliminate the carbonic acid poison already formed in the blood; and 2, to prevent as far as possible its further formation.

The utility of an emetic, as the *first* means of treatment in stomach-poisoning, is not more obvious than the instant institution of artificial respiration, the sole eliminator of the blood-poison, in asphyxia; and as in the former we would not administer a new dose of the poison, so in the latter we must not, if we could, prematurely accelerate the circulation of the blood—that is, the *formation* of additional poison, by warmth; &c.

Without due artificial respiration, every means of augmenting the circulation must be injurious. Excited or imitated respiratory movements are the sole means of eliminating the carbonic acid poison from the blood—the *unicum remedium* in asphyxia; and if the want of oxygen plays any part in the state of things which exists in asphyxia, in addition to the excess of carbonic acid, it is still by respiration alone that it can be supplied. The warm-bath and the other measures for restoring the circulation, *without this* as the *preliminary* measure, if they have any influence at all, *can* only augment the formation of the poison.

These latter measures must therefore be delayed. The *first*, the *sole first*, remedy is—artificial respiration.

But the modes hitherto proposed for the institution of respiration are, for reasons which I proceed to give, either inefficient or absolutely injurious.

These modes of inducing artificial respiration are of two kinds: the *first* may be compared, in its operation, to the action of the *forcing-pump;* the *second*, to that of the *suction-pump ;* and both have been used with a disregard to the all-essential consideration of *posture*.

To commence my observations on this *last* point, I must remark that when the subject is kept in the *supine* position, an event occurs which renders every attempt at inducing respiration absolutely nugatory: *the tongue falls backwards, carries with it the epiglottis and closes the glottis or entrance into the windpipe and air-passages!* The introduction of air, except by accident, and in the case in which a laryngeal tube or tracheotomy is employed, is utterly impossible!

This obstacle, as I shall explain in the succeeding section, is obviated at once by reversing the position from the supine to the *prone!*

Mr. Williams, the Society's Superintendent in Hyde Park, has observed the cheeks to become inflated and air to escape from the intestine, in cases in which artificial respiration has been attempted by the bellows; and it is certain that the plan of Leroy can have little efficacy.

The following experiment has been repeated many times, and has been witnessed by George Webster, jun. Esq, of Dulwich, Mr. Williams, and other gentlemen:

Exp. 14.—The dead subject being placed in the *supine* position, and pressure made on the sternum and ribs, a little gurgling was heard in the throat; but, the pressure being removed, there was *no* evidence of *in*spiration. The subject being then turned into the *prone* position, and pressure being made on the spine and the ribs, and removed as before, there was in general free expiration and *in*spiration.

One object of the succeeding section will therefore be to describe and recommend the plan of *prone*-respiration, or PRENOPNŒA; (from *πρηνης*, pronus).

But another objection applies to the mode of inducing artificial respiration having the character of the forcing-pump.

In order to accomplish this kind of respiration, a degree of force must be used, sufficient to raise the bony and other structures of the thorax and depress the diaphragm—a degree of force which both anticipation and experience prove to be injurious to the delicate structure of the lungs. Legallois and M. Leroy found these structures variously lacerated by this measure in experiments on animals—the air so impelled sometimes passing into the capillary vessels, and sometimes even into the cavity of the thorax.

Two facts are obvious from the considerations laid before the reader in this and the preceding sections: the first, that artificial respiration must precede and accompany all other measures for the recovery of the patient affected by the suspension of this vital function; and secondly, that some other modes of artificial respiration than those hitherto proposed must be devised, before we can be said to treat the case on scientific grounds, or in an efficient manner.

There are two other points to be noticed: sometimes fluids of various kinds occupy the fauces and present another impediment to the entrance of air into the lungs: these fluids may be—1, a portion of the water from which the patient has been rescued; 2, the natural saliva and mucus of the internal mouth, not now swallowed as in health; 3, foam; and, especially, 4, fluids which have regurgitated from the stomach on moving the body—an event of the most ordinary occurrence.

These impediments to respiration can again only be effectually removed by placing the patient—*in the prone position!*

In the second place, any measure of inducing the artificial inspiration of air, if used with too great *rapidity*, is apt to close the larynx by external pressure on its sides:

Exp. 15.—I removed the larynx and wind-pipe, and attached the nozzle of the syringe to the lower part of the latter: on drawing up the piston, the cordæ vocales were seen to be drawn together whenever the piston was moved upwards with too great rapidity, and all ingress of air into the wind-pipe utterly prevented!

The obvious conclusion is, that, whenever we attempt artificial respiration, the procedure must be effected with gentleness and slowness.

§ VIII.—*New Modes of Treatment of Asphyxia.*

The reader of the preceding section will readily anticipate the principal points in this.

The patient is to be taken from his former supine position and laid *prone on his face.*

In this position, the tongue falls forwards, draws with it the epiglottis, and leaves the glottis open. The tongue may even be *drawn* forwards, to *secure* its removal and that of the epiglottis, from the rima glottidis. All fluids will flow from the fauces and mouth.

In order that the face may not come into contact with the ground, the patient's hands and arms are to be carried upwards and placed under the forehead.

It will now also be perceived that the thorax and abdomen will be pressed by a force equal to the weight of the body. This pressure will induce *ex*piration. And, if necessary, additional pressure may be made on the posterior part of the thorax and abdomen. This will induce slight additional expiration.

This latter pressure may then be removed. Its removal will be followed by slight *in*spiration. The weight of the body is then to be raised from the thorax and abdomen. This may be done in various ways:

First, the body may be gently turned on its side by an assistant placing one hand under the shoulder and the other under the hip of the opposite side. This will remove *in great part* the weight of the body from the thorax and abdomen, and allow all but one side of the thorax to expand. In this manner a fair degree of *in*spiration is induced! *And thus, without instruments of any kind, and with the hands alone, if not too late, we accomplish that respiration which is the sole effective means of the elimination of the blood-poison!*

Or, in the second place, the body may be raised gently, but steadily, by one or two assistants placing the hands under the shoulders. But this requires a good deal of force, and seems practically to be of minor efficacy.

There is a *third* mode of procedure It requires the aid of *two* assistants. Each places one hand under the shoulder and the other under the hip, and lifting together, they raise the body nearly or entirely from the table. But this procedure appears to be less efficacious than rotation, the spine probably becoming flexed.

For some experiments on this mode of inducing artificial respiration, which I designate *postural* respiration, or THESIOPNŒA (from θεσις, positio), I am indebted to

Edward Long Fox, Esq. of Bristol. They were performed by that gentleman, with the aid of Mr. Hunter and Mr. Bowles, at St. George's Hospital.

Exp. 16.—" The recently dead body was placed in the *prone* position ; as this was done, considerable expiration took place. Pressure being made on the back and ribs, further expiration took place, but only to a slight extent. On removing this pressure, slight inspiration took place. On turning the body on the left side, violent inspiration took place, which ceased as soon as the body was turned beyond the quarter of a circle.

" The body was again pronated and again rotated. The expiratory and inspiratory effects were most marked. On one occasion, 120 bubbles of air (in a bent glass tube through which the patient breathed) were distinctly counted during one expiration ; and the inspiration seemed to be quite in an equal degree, although, from its greater rapidity, the bubbles could not be counted.

Exp. 17.—" The body was turned into the prone position : considerable expiration took place, which was much augmented by the pressure of the hands on the back. On removing the pressure, a little inspiration took place. The body being then rotated on the right side, considerable inspiration took place, whilst moving through one fourth of a circle ; on continuing the rotation, inspiration continued until the body was half way between the table and the lateral position, when it ceased." *See* p. 6.‡

Exp. 18.—In some experiments made at the St. Mary-le-bone Infirmary, already noticed, the dead subject being first placed on the back, and pressure made on the thorax, a little expiratory noise was made; but there was no inspiration on its removal; the subject being turned prone on the face, *both* expiration and inspiration were distinctly observable on making and removing pressure along the course of the dorsal spine.

This manœuvre may therefore be *added* to that just described: when the patient is laid quite prone, gentle pressure may be made on the spine and ribs; this being removed, the patient may be *turned,* or *raised;* and so on.

Thus, in the prone position, the glottis is unobstructed, and pressure equal to the weight of the body is made on the thorax and abdomen; and to the latter a little may be added by making gentle pressure along the spine; expiration is effected; the pressure along the spine being removed, and the patient turned or raised, so as to remove all pressure from the thorax and abdomen, an equivalent inspiration is accomplished.

These changes should be alternated at the rate of about *sixteen* times in a minute, and *not more,* and gently and equably.

It is scarcely necessary to add that this mode of respiration must be long and perseveringly pursued; and now that respiration is being performed, every other means of restoration may be *superadded.*

Sufficient has been done to show the practical utility of this, the only certain, safe and efficacious mode of inducing artificial respiration; but it is obvious that it still remains to ascertain the exact *value* of this and of other measures for succouring the asphyxiated, not by what is called experience, but by a series of careful and *comparative experiments.*

The clothes of the patient may meantime be changed for others warm and dry, which must be contributed by the bystanders. For I must now observe that I have all along supposed the patient taken out of the water at a distance from medical or other assistance, except that which benevolent persons accidentally near the spot may be able to lend; for no time must be lost in his removal.

All who are so present should be instantly employed: the most able in effecting respiration; of the rest, *four* should seize the limbs with their hands and rub them with firm pressure upwards. The warm-bath is not to be compared with this mode of restoring warmth, and not warmth only, but the circulation, if it be pursued with energy. The blood is driven upwards, and though venous, *may* stimulate the heart.

But I must repeat that all these modes of procedure must be held as perfectly *subsidiary* to the one only remedy, *prone and postural respiration.* There is one hope, and only one hope; one remedy: it consists in eliminating the carbonic acid blood-poison from the blood by respiration.

Having thus given in detail my views of former modes of procedure and of some new ones, I now proceed to place before my readers a recapitulation of the treatment to be systematically adopted in asphyxia, in the form of *Rules.* which, I humbly think, may with great advantage be substituted for those formerly recommended:

§ IX.—*New Rules for the Treatment of Asphyxia.*

The *Rules* for the treatment of asphyxia may be divided into two series :

1. The essential, or the means to be adopted in every case ;
2. The occasional, or the means to be further tried when convenient.

I. *Rules to be adopted in every case:*

I. Send with all speed for medical aid, articles of clothing, blankets ; &c. but

II. Lose not a moment of time ; treat the patient on the spot, in the open air, exposing the face and chest freely to the breeze (except in too cold weather) ; then—

To excite Respiration—

III. Place the patient gently and for a moment on the face, to allow any fluids to flow from the mouth ;

IV. Then raise the patient into the sitting posture, and endeavour to *excite* respiration ;

1. By irritating the nostrils by *snuff ; hartshorn ;* &c.
2. By irritating the fauces by a *feather ;* &c.
3. By dashing hot and cold water alternately on the face and chest. If these means fail—

To imitate Respiration—

V. Replace the patient on his face, his arms under his forehead (*vide* frontispiece), and—

1. *Turn* the body gradually, but completely, on the *side*, and a *little more*; and then again on the face, alternately;
2. When replaced, apply pressure along the back and ribs, and then remove it, and proceed as before;
3. Let these measures be repeated gently, deliberately, but efficiently, and perseveringly, *sixteen* times in the minute, *only*.

VI. *Continuing* these measures, rub all the limbs upwards, making firm pressure, *energetically;*

VII. Replace the wet clothes by such other covering, &c. as can be procured.

Omit the warm-bath until respiration be re-established.

II. *Further Rules to be adopted when convenient:*

I. Administer warm food or gentle stimulus by means of the stomach-pump;

1. By the stomach, or
2. By the rectum;

II. Apply galvanism;
  1. Along the diaphragmatic nerve, or
  2. Through the diaphragm and intercostal muscles;

III. Induce the inhalation
  1. Of Oxygen;
  2. Of dilute pure ammonia*;
  3. Of stimulants.

IV. Institute the transfusion of arterial blood into the brachial vein.

On the first part of these Rules no further explanation is necessary. On the second I now propose to make a few concluding observations.

Of the value of the ingestion, either into the stomach or into the rectum, of a little warm food or gentle stimulus, when the patient is in a condition to admit of it, there can be no doubt. It will only require to be done with prudence. The pharyngeal tube will be sufficient, if necessary, in one case, the ordinary clyster apparatus in the other.

Of the value of galvanism I have not formed a very high opinion. If the current be passed along the diaphragmatic nerve or through the diaphragm itself, or through the intercostals, respiratory movements may be excited. But I do not know that they would possess any advantage over similar movements induced in any other way.

It is still a question whether the action of the heart may be beneficially excited by galvanism. But the careful experiment should be tried.

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* As an *antidote* to the carbonic acid blood-poison.

The galvanic current passed through the limbs would excite their muscles to contract and so induce the propulsion of the blood along the veins. Whether this mode of promoting the venous circulation would possess any advantage over the mode by friction and pressure, requires to be determined by experiment.

I cannot regard the inhalation of oxygen as a very promising measure. Its value requires to be submitted to *much* further trial and investigation.

The inhalation of dilute but pure ammonia appears to me to have more in it of promise. The blood is overcharged with carbonic acid: the inhalation of ammonia would neutralize this carbonic acid and form the carbonate of ammonia; the carbonic acid is the blood-poison; the carbonate of ammonia is free from any deleterious quality.

Of the effect of the transfusion of arterial blood taken from a bystander into the brachial vein, little can be conjectured without experiment. The operation might be made simple enough, and an experiment long ago performed by Stenon, and since repeated by many physiologists, seems to indicate that much good might result from the measure. The experiment consists in applying a ligature round the aorta: the lower extremities soon die to sensation and movement; but if the ligature be removed, life is restored.

It cannot be repeated too often or too earnestly that all these remedies of the second class, if I may so designate them, must be regarded as entirely subsidiary to the constant persistence of respiration.

The Warm-Bath.

It will be seen that I have entirely omitted the use of the warm-bath.

This measure is perfectly useless, not to say injurious, unless artificial respiration be simultaneously administered, and this administration is incompatible with the posture implied by the use of the warm-bath. To use the warm-bath is, therefore, to renounce the only hope, the only remedy in asphyxia.

It is true that the warm-bath has been commended by some of the members of the Royal Humane Society; but it is as emphatically condemned by the Superintendent of the Society at Boulogne, by theory, and by experiment.

Experiment proves, as seen in the *Tables* adduced (pp. 21, 22), from Edwards and M. Brown-Séquard, that life is more protracted in the case of suspended respiration at cool temperatures than in temperatures more elevated; and the experiments given, p. 23, were performed at the Receiving House in Hyde Park, the first two being witnessed by the Secretary of the Society and by Dr. Christian.

An animal lives longest *without* respiration in a temperature of about 60° Fahr. With respiration, the temperature may be carefully raised to 98° .

The only hope from the use of the warm-bath is that by exciting the circulation and the formation of carbonic acid, the blood-poison, it *might* induce *gasping* or the pseudopnœa, which, mingling inspiration with its other phenomena, might lead to normal respiration. But, I repeat it, experiment and the experience of the Superintendent at Boulogne are alike against this hope.

§ X. *On the Asphyxia of Still-born Infants.*

The difference in regard to the power of supporting the suspension of respiration in the young animal *before* and *after* the commencement of respiration has been noticed by the illustrious Harvey, by Buffon, by Legallois, by Edwards, &c. The same difference obtains in regard to the very young and the less young of certain species of animals which have breathed.

We all remember the celebrated question of Harvey, and the equally celebrated experiment of Buffon. The fœtus in general breathes less, developes less heat, and supports suspension of respiration better than the infant born.

The differences in regard to age in rabbits is shown in the following beautiful *Table* of Legallois:

Legallois' Table.

Influence of age upon the duration of life. Rabbits asphyxiated by immersion in water.

Days old.	Sensibility*.	Gaspings.
1	15′	27′
5	10′	16′
10	4½′	5½′
15	3′	4′
20	2¾′	3¼′
25	2′	2¾′
30	1½′	2½′

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* Legallois observes (Ed. Paris, 1812, p. 79)—" J'essaye la sensibilité en pinçant les oreilles, les pattes et la queue, et j'en

The same fact is observed in puppies and kittens. The guinea-pig is, however, an exception to the rule; the very young of this species holding nearly the same rank in this respect as the adult.

In regard to the human subject, we learn from the experiments of MM. Andral and Gavarret that the *quantity* of carbonic acid exhaled in respiration *in*creases from the age of eight to that of thirty years; asphyxia will of course be the more promptly fatal in the inverse order. After the age of thirty, the quantity of the carbonic acid poison *de*creases.

The male subject exhales more carbonic acid than the female, the robust than the feeble, and will consequently perish more promptly by the suspension of respiration; a result the opposite again, I believe, to the popular opinion.

In treating the still-born, the great object is, as usual, to *excite* respiration; this is *most* effectually done by plunging it into a *cold* and (—not a *warm* but—) a *hot* bath alternately. This means of exciting respiration in the still-born infant was first put to the test of experiment, at my suggestion, as I have already stated, by my late deeply regretted friend, Mr. Henry Smith.

The just temperatures of these baths have not yet been ascertained. I would suggest from 50° to 60° Fahr. for the cold, and from 98° to 102° Fahr. for the hot bath.

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note l'extinction au moment où ces pincements ne déterminent plus aucun mouvement." "Assez souvent il existe encore un peu de sensibilité à l'anus, quand il n'y en a plus dans ces parties."—Phenomena, in fact, of reflex action.

The immersion should be momentary; the alternations quick;—in order that no time may be lost.

If this means fails, and if irritation of the nostrils, the face, and the general surface, has been tried in vain, respiration must be *imitated* in the manner already described—*prone*-respiration and *postural*-respiration being fully and perseveringly instituted.

§ XI.—*On Secondary Asphyxia.*

All is not safe even when the patient seems to be restored from asphyxia.

One of the puppies of Buffon's experiment died some time afterwards on the same day.

On one occasion I placed a sparrow and a mouse in the same limited portion of atmospheric air. After a time, the sparrow began to open its mouth and gasp, and was removed; and after a longer interval, the mouse presented the same phenomena, and was removed in its turn. The bird died the next day; the mouse on the second following day—of secondary asphyxia.

Sir Humphry Davy was seized with alarming symptoms on the evening of the day on which he had attempted to breathe carburetted hydrogen gas.

On one occasion a soldier was taken out of the Thames in a state of asphyxia. Animation was restored. But, many hours afterwards, he was seized with convulsions and expired.

From these and other similar facts we must deduce the conclusion, that our watchful care and our remedies must be continued after apparent danger is over. There is still a *hidden* and remoter danger; the consequence of the poisoned state of the blood—of *secondary* asphyxia.

The patient should be *kept* in a cool atmosphere, *exposed* to the breeze, be *made* to take deep and free inspirations voluntarily, and active exercises should, as far as possible, be enjoined, in order that the blood may be purged of its carbonic acid poison, whilst its circulation is promoted. Carbonic acid *in the blood* does not excite respiration until it exists in sufficient quantity to induce gasping by acting centrically on the spinal marrow. It is its presence in the air-cells which induces inspiration and panting, as a *reflex* phenomenon. Its elimination, therefore, requires excited, voluntary, or artificial respiratory movements.

§ XII.—*Recapitulation.*

1. The movements in normal respiration are *reflex* or *dia*staltic;

2. The respiratory movements in Asphyxia are *direct* or *ec*staltic;

3. The *former* are excited by the carbonic acid exhaled from the blood into the air-cells, in contact with the filaments of the pneumogastric nerve; and

3. When this carbonic acid is in excess, it induces *panting;*

5. The *latter* are excited by the carbonic acid *retained* in the blood and brought into contact with the medulla oblongata and medulla spinalis;

6. They take the specific form of *gasping*, with jerks, tottering movements, and eventually of paraplegia;

7. The carbonic acid retained in the blood acts as a most deadly *poison;* there is ONE mode of eliminating this poison,—Respiration,—excited or imitated;

Respiration is to the Carbonic Acid-Poison in the Blood, what Vomiting is to Poison in the Food;

8. The quantity of this carbonic acid poison formed is proportionate to the rapidity of the circulation; to augment the circulation *without* effecting the elimination of this poison by artificial respiration, as by the warm-bath, shampooing, &c. is to augment the quantity of the poison, and to accelerate the death of the patient!

9. In order to effect artificial respiration, it is essential to place the patient in the *prone position;* otherwise the tongue and any fluid in the mouth fall backwards and close the glottis or entrance into the wind-pipe;

10. In adopting the prone position, a degree of pressure is at the same time made on the thorax and abdomen equal to the weight of the body, and *expiration* is produced.

11. A little pressure now made along the spine augments the expiration;

12. On removing this pressure, *inspiration* to an equal extent occurs;

13. And by gently *rotating* the body on the side, *further inspiration occurs:*

14. By repeating these manœuvres we produce the most efficient artificial respiration—the *only* effectual means of treatment.

15. When artificial respiration is thus effected, and the carbonic acid poison is thus eliminated from the blood, the application of friction with pressure along the veins, and of warmth, may be superadded;

16. The *warm-bath*, excluding *prone* and *postural* respiration, should only be administered when the respiration is not suspended, or when it is perfectly restored.

Lastly, I must repeat that the foregoing pages are a mere Abstract of a considerable investigation scarcely more than just begun. Much remains to be done.

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* In *perfectly* pure nitrogen or hydrogen gas the animal dies more speedily even than when submerged under water—the oxygen already in the blood being probably exhaled. (*See* p. 15). The spark of life becomes almost instantly extinct with phenomena which are quite peculiar.

One of the most extraordinary results of my experiments is this: a mouse will *live* in an atmosphere of nitrogen and oxygen, in which there is *so little* oxygen, that a lighted taper is immediately extinguished, flame and spark,—and *die* in an atmosphere of carbonic acid and oxygen, in which there is *so much* oxygen, that a taper blown out, leaving a spark, is immediately re-inflamed. It is not the want of oxygen, but the excess of carbonic acid, which proves fatal.

FINIS.

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